MEASURED VERSUS CALCULATED OXYGEN SATURATION OF ARTERIAL BLOOD: A CLINICAL STUDY*

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MEASUREMENT of the oxygenation of the blood is now an accepted assessment of respiratory and cardiac function. Various manipulations of the numbers derived from direct measurement of oxygen tension in both arterial and mixed venous blood can give a fairly accurate picture of the patient's status in terms of cardiac output, alveolocapillary membrane oxygen diffusion, peripheral circulation, and tissue oxygenation. With the advent of self-calibrating, totally automated machines to measure oxygen tension, many clinical laboratories no longer perform direct saturation measurements but furnish the physician a saturation value calculated directly from oxygen tension and pH. Simple transcription of a normal oxyhemoglobin dissociation curve to linear form enables us to convert one system of measurement (i.e., oxygen tension) into another (oxygen saturation) and to utilize the second value in further calculations to provide more information about the patient's state. But patients do not always fit into direct slide-rule calculations, and a saturation value derived from an oxygen tension, subject to error of 10% or more, may lead to totally erroneous conclusions when used for further determinations planned to evaluate and correct the condition of the sickest patient.

Among intensive-care-unit patients who are at greatest risk of tissue hypoxia, whether from pulmonary failure, cardiac decompensation, inadequate oxygen transport, or derangements at the cellular level, accurate measurement of oxygen saturation is essential to plan rational therapy for

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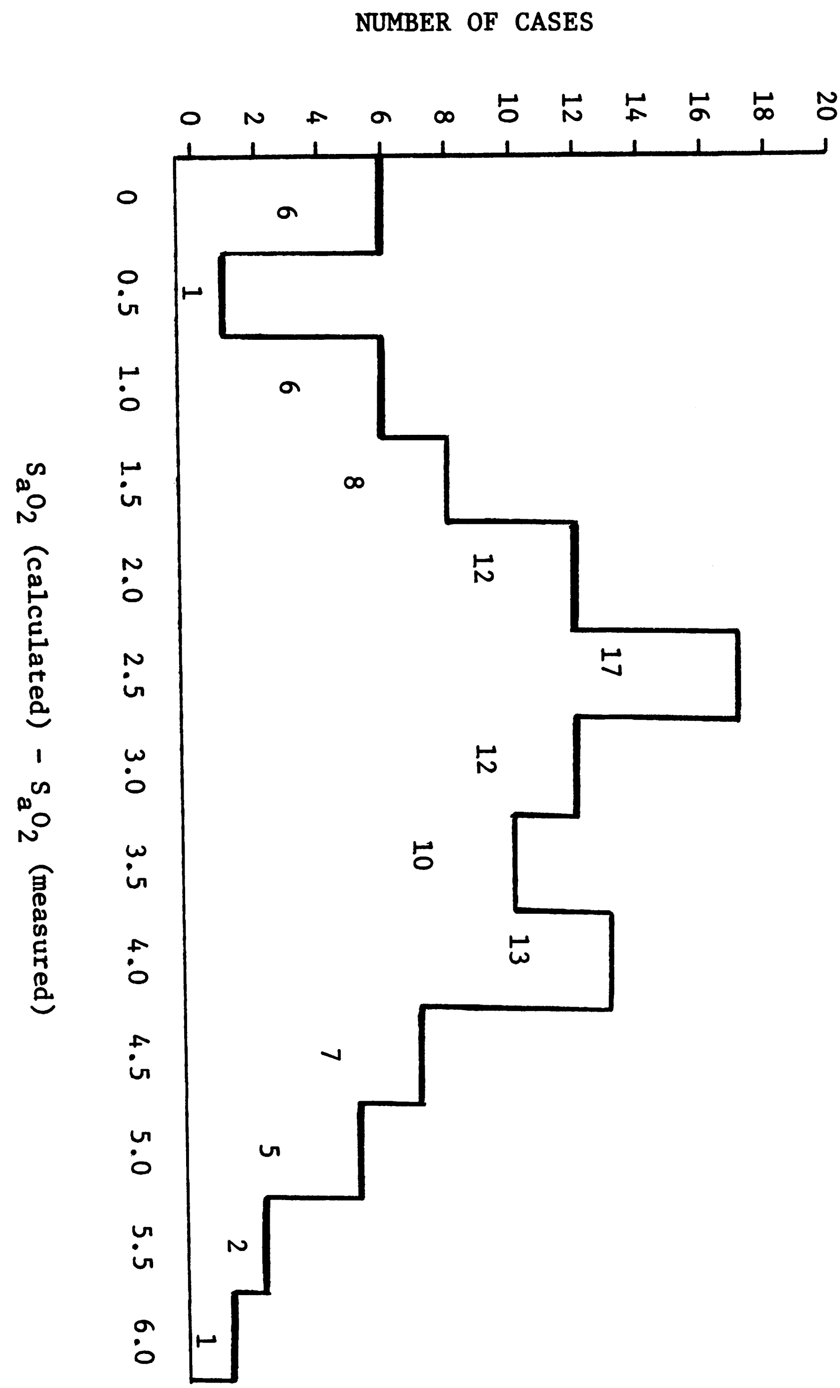

Distribution of discrepancies between calculated and measured oxygen saturation (S_aO_2) (100 cases)

TABLE I. REPRESENTATIVE pH VALUES IN THE SERIES, SHOWING LACK OF CORRELATION BETWEEN ACID-BASE STATUS AND DISCREPANCIES IN SATURATION VALUES

Case number	*pH*	*P_aO_2 (torr)*	*Calculated saturation (%)*	*Measured saturation (%)*	*Difference (C − M) (%)*
18	7.31	54.5	96	93.5	2.5
60	7.31	113.8	99	95.0	4.0
79	7.40	95.7	97	95.5	1.5
93	7.40	120.7	99	93.0	6.0
97	7.40	155.9	99	94.0	5.0
32	7.54	69.8	96	95.5	0.5
70	7.54	61.6	95	92.5	2.5
9	7.56	79.7	96	93.5	2.5

these disorders. To assess the validity of calculated oxygen-saturation values, we studied actual correlation, or lack thereof, between measured and derived values.

MATERIALS AND METHODS

One hundred arterial blood samples were taken from 35 patients being treated by mechanical ventilation for conditions varying from flail chest to sepsis with multiorgan-system failure. All samples underwent arterial blood gas determination using the Corning pH/Blood Gas Analyzer Model 165, and oxygen saturation was determined by the spectrophotometric method (American Optical Micro-Oximeter). Saturation was calculated from the measured oxygen tension (P_aO_2) using the Blood Acid/Base Calculator made by Instrumentation Laboratory, Inc. Calculated and measured values were then compared.

RESULTS

Oxygen tensions for the group ranged from 54 to 329 torr, with saturations from 90 to 99%; in six samples calculated and measured saturations were identical. In the other 94, however, measured were from 0.5 to 6.0% lower than calculated saturations. The average error was 3.3%, with half of the pairs differing by 3% or more (see figure). There was no relation between pH and size of error (Table I), between oxygen tension and error (Table II), nor between carbon dioxide tension and error (Table III). Indeed, the single largest discrepancy, 6.0%, occurred at pH 7.40 and

TABLE II. REPRESENTATIVE OXYGEN TENSION IN THE SERIES, SHOWING NO CORRELATION BETWEEN P_aO_2 AND MAGNITUDE OF ERROR IN CALCULATING SATURATION

Case number	*pH*	*P_aO_2 (torr)*	*Calculated saturation (%)*	*Measured saturation (%)*	*Difference (C – M) (%)*
18	7.31	54.5	96	93.5	2.5
11	7.51	57.1	93	90.5	2.5
79	7.40	95.7	97	95.5	1.5
10	7.42	104.4	99	95.4	3.5
77	7.47	201.5	99	96.5	2.5
82	7.41	329.9	99	94.5	4.5

TABLE III. RANGE OF CARBON DIOXIDE TENSION IN THE SERIES, DEMONSTRATING LARGE ERRORS IN SATURATION DETERMINATIONS OCCURRING AT VARIOUS POINTS

Case number	*pH*	*P_aCO_2 (torr)*	*P_aO_2 (torr)*	*Calculated saturation (%)*	*Measured saturation (%)*	*Difference (C – M) (%)*
95	7.52	24.8	82.3	97	92.0	5.0
93	7.40	29.7	120.7	99	93.0	6.0
96	7.34	34.0	145.6	99	94.0	5.0
97	7.40	41.6	155.9	99	94.0	5.0
14	7.40	47.2	124.5	99	96.0	3.0
59	7.38	49.6	125.7	99	94.5	4.5

P_aO_2 of 120.7 torr, both well within the range of accuracy of the equipment.

DISCUSSION

In the average clinical situation, an error of 3% in oxygen saturation makes little difference in management unless it occurs at the very lower limit of safety, that is, at oxygen saturations of 90% or below. Even so small an error, however, can lead to a significant overestimation of arteriovenous shunting. It would be interesting to pursue this experiment at the more abnormal ends of the spectrum, i.e., with both pH and oxygen tension above and below accepted norms, to determine whether calculated errors in saturation increase accordingly, but in the clinical setting such a trial clearly is not feasible.

Conclusion

The ease with which a now standard laboratory value, the oxygen tension, can be measured, in contrast to the more cumbersome direct measurement of oxygen saturation, makes it tempting to accept a derived saturation value as valid for further computations with potentially dramatic revision in patient care, but such derivations are approximations at best and, when an accurate value is essential, direct measurement is also essential.